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PRELIMINARY INSTRUCTION BOOK
for

MODEL 71
SQUARE WAVE GENERATOR

MEASUREMENTS CORP.
Boonton, N. J.

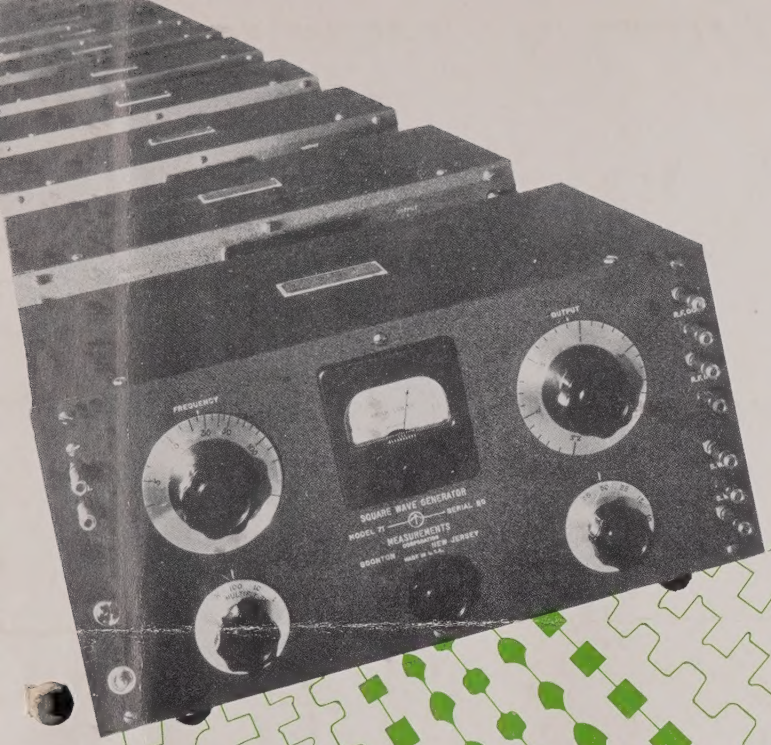
TEST EQUIPMENT SECTION
A.E.E.L.—N.A.D.S.

MP MASTER
MA24723



A. G. Schafer

TEST EQUIPMENT SECTION
A.E.E.L.—N.A.D.S.



The Technique of Square Wave Analysis

MEASUREMENTS CORPORATION
Boonton New Jersey

Ⓐ Square Waves

The square wave is nothing more than Heaviside's "Unit Pulse", repeated at suitable intervals to permit direct observation of the wave shape on a cathode-ray oscilloscope. Varying the frequency of the square wave expands or compresses the time base to facilitate observation of either the squareness of the front or the slope of the top. For reference, see an article by Gilbert Swift—"Amplifier Testing by Means of Square Waves" —*Communications*, February, 1939

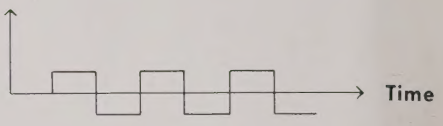


Fig. A

Ⓑ Low Frequency Cutoff

Low frequency cut off in a simple resistance coupled amplifier is characterized by the wave shape of Figure B. This is a measurement of the amplifier relaxation time. Networks containing non-linear components, such as iron cored reactors, may show considerably different low frequency characteristics.

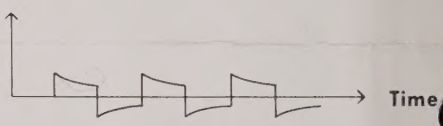


Fig. B

Ⓒ High Frequency Cutoff

High frequency cut off in a simple resistance coupled amplifier is indicated by the characteristic of Figure C. Networks with sharper cut off properties will have somewhat different characteristics.

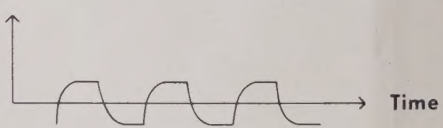


Fig. C

Ⓓ Transient Oscillations

Transient oscillations in networks frequently do not show up in the presence of sine wave tests. A sharp wave front, such as a square wave, is an ideal for studying transient oscillations. Reference—see A. V. Bedford, "Transient Response of Multistage Video-Frequency Amplifiers", *Proceedings of the IRE*—April, 1939.

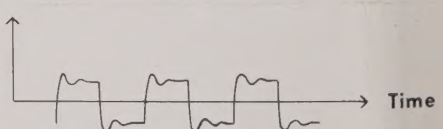


Fig. D

Ⓔ Square Wave Modulation

By applying square wave modulation to a carrier of suitable frequency, both amplitude and phase characteristics as well as the transient properties of r.f. amplifiers can be studied. This new technique permits rapid alignment of wide-band intermediate frequency amplifiers. See H. E. Kallmann—"Portable Equipment for Observing Transient Response of Television Apparatus"—*Proceedings of the IRE*—August, 1940.

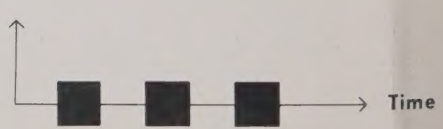
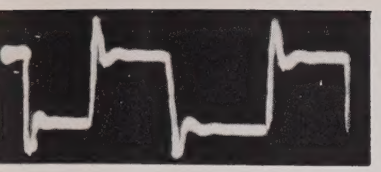


Fig. E

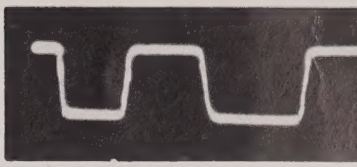
Spurious Resonance



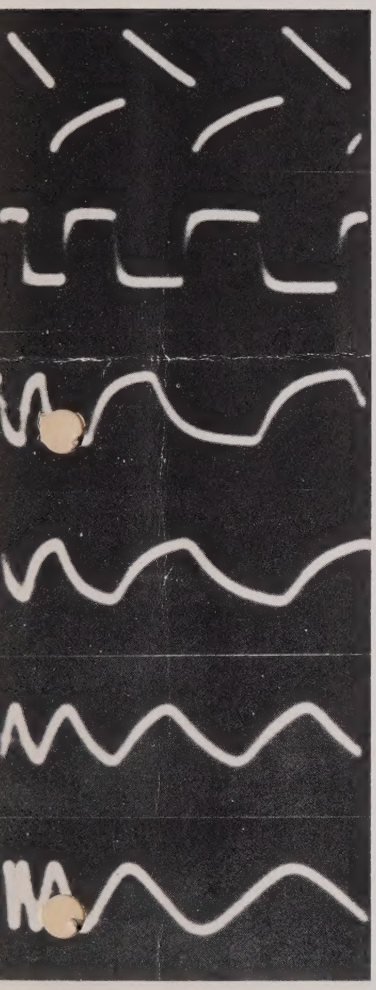
with inverse feed back — no load on output transformer

5,000 cycle square wave

with inverse feed back — light resistance load on output transformer



Recording Amplifier



WITHOUT INVERSE FEEDBACK (*Light Load Resistance*)

40 cycle square wave

1,000 cycle square wave

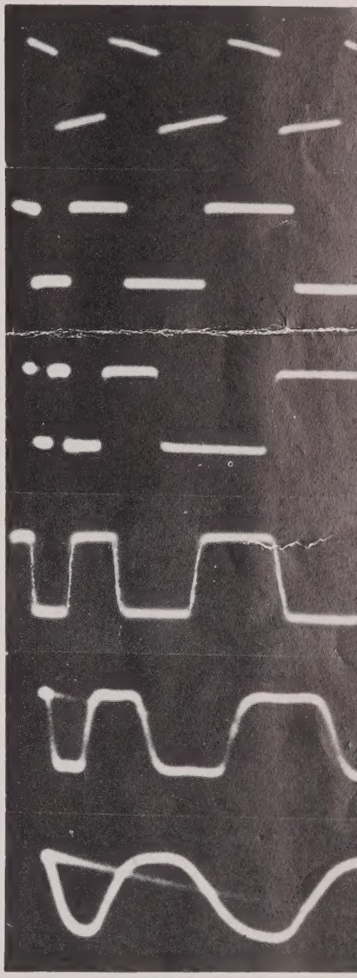
3,000 cycle square wave

5,000 cycle square wave

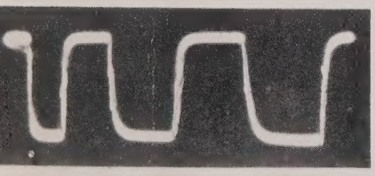
10,000 cycle square wave

20,000 cycle square wave

WITH 30 DB INVERSE FEEDBACK (*Light Load Resistance*)



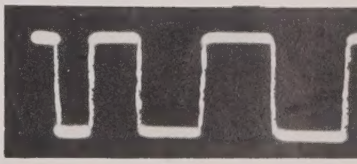
Grid Volume Control



500,000 ohm input grid potentiometer set for one-half maximum volume

2,000 cycle square wave

500,000 ohm input grid potentiometer set for maximum volume



FM Band Pass Filter



sharp position

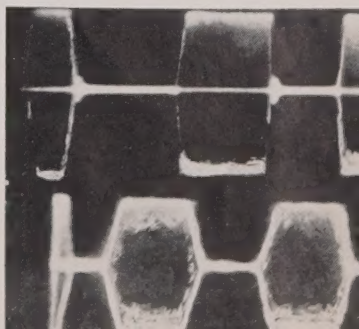
10,000 cycle square wave modulation on 1700 kc mid-band carrier

Broad ± 200 kc @ 1 db down

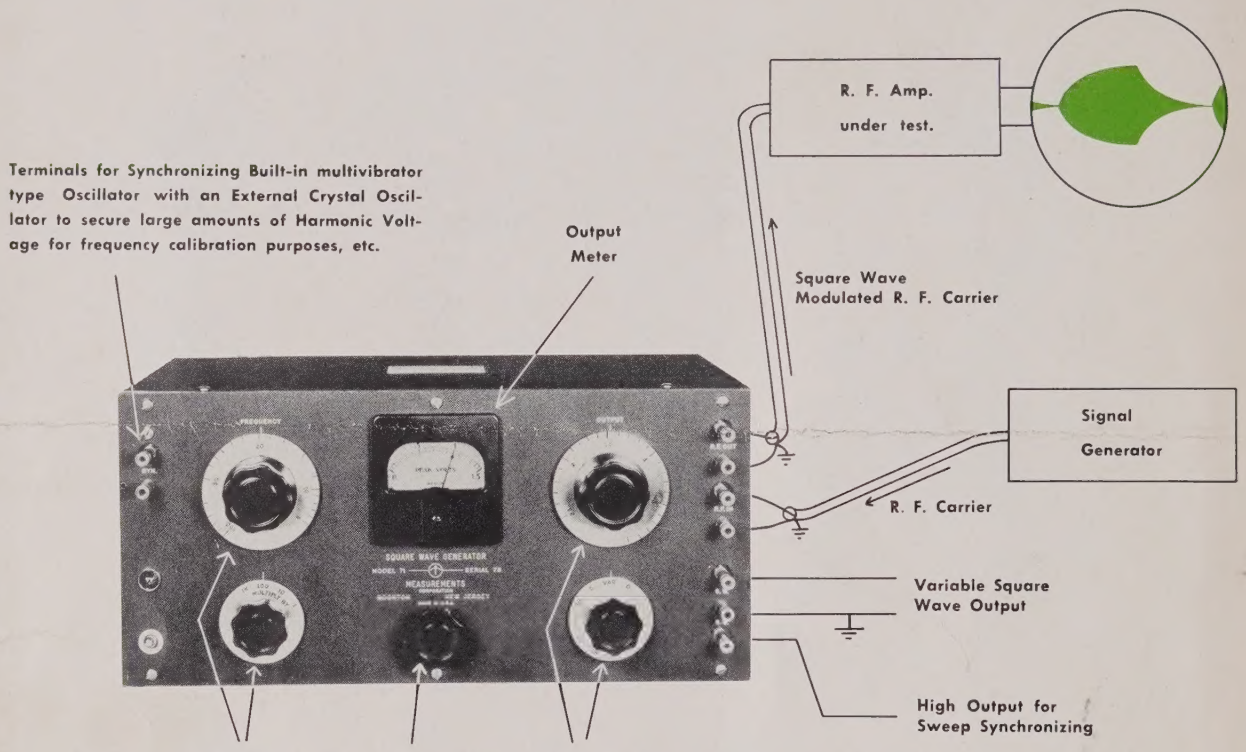
effect of detuning carrier from mid-band

Broad ± 200 kc @ 1 db down

30,000 cycle square wave modulation



Model 71 Square Wave Generator



R. F. MODULATOR:

5 Volts maximum carrier input—Translation gain is approximately unity—Output impedance is 600 ohms.

POWER SUPPLY

115 Volts 60 cycles—self-contained—no batteries.

DIMENSIONS:

Panel—7" x 15", depth 7½". Weight approximately 15 lbs.

PRICE

$160 complete with tubes, f.o.b. Boonton, N. J.

PERFORMANCE:

- Checks Audio Circuits
- Checks Video Circuits
- Checks Television and FM R. F. amplifiers
- Checks Receiver AVC Time Constants, Recovery Time, etc.
- Automatic Key for Transmitter Performance Tests
- Harmonic Generator for Frequency Calibration

MEASUREMENTS CORPORATION

BOONTON NEW JERSEY

PRELIMINARY INSTRUCTION BOOK
for the
MODEL 71 SQUARE WAVE GENERATOR

The Model 71 Square Wave Generator is a completely self-contained source of square waves covering the fundamental range 5 cycles to 100,000 cycles per second. This makes it suitable for testing the characteristics of many types of amplifiers and networks over the range from one cycle to several megacycles per second, covering the usual audio and video ranges.

The usefulness of square waves for determining the phase and frequency characteristics of networks depends upon the fact that these characteristics are completely determined if the response of the network to the application of the unit function of voltage is known.

Square waves are merely the unit function of voltage, cyclically repeated at suitable time intervals. Thus the response of the network to the unit function also repeats cyclically, and by placing the output wave upon the deflecting plates of an oscilloscope, direct observation of the response against time is obtained, and the characteristics of the network thus obtained by direct observation and interpretation of the patern seen. Roughly speaking, the application of a square wave of repetition frequency f allows direct determination of the frequency characteristics of the network down to a frequency of f/10 and up to a frequency of f x 10, sometimes higher. Thus the usual audio frequency network can be tested completely over the range 5 cycles to 20 or more kilocycles by the application of only two different square wave frequencies, say 50 cycles and 2 kilocycles. The testing of video networks is corresponding simplified, though to an even greater degree, for phase relationships which are of great importance in video circuits can be determined much more conveniently and rapidly by the square wave technique than by any other known method.

The interpretation of the pattern seen on the oscilloscope screen in terms of actual phase and frequency characteristics is a matter requiring some experience, since some of the relationships are not immediately obvious from the pattern. It is true, however, that all of the information which may be desired about the action of any circuit is contained in the output wave pattern, and is available to the observer who knows what to look for; therefore including not only the more commonly known and measured characteristics, but also others less easily measured and hence not commonly appreciated. The increased speed of obtaining the result, as well as the greatly increased amount of information about the circuit which is made available by the square wave technique, will pay any technician handsomely if he will take the time to learn the technique and to become experienced in interpreting the results obtained. This is particularly true in the television field, but even in the audio frequency field it is becoming evident that certain phase and transient relationships commonly neglected, may have an important bearing

Model VI Square Wave Generator

for the

MODEL VI SQUARE WAVE GENERATOR

on the overall fidelity and naturalness of reproduction of sound systems. These relationships are difficult to determine by sine wave testing methods, but become simple in the square wave testing technique.

One important distinction between the sine wave and the square wave technique, which must be kept in mind, is that in sine wave testing, amplitudes are of prime importance and must therefore be measured, thus requiring at least two meter readings at each frequency of measurement. In the square wave method the answer is obtained by the interpretation not of amplitudes but of wave shapes, which are generally independent of amplitude as long as no overload is encountered. Thus no measurements of amplitude are required, no meters need be set or read, and no expensive attenuation systems are required. The Model 71 is definitely not a standard of amplitude, even though for convenience it includes an output meter, and a calibrated attenuator. These are meant to supply only an approximate idea of output voltage and a convenient method of varying this voltage, and are ~~in~~ not standards of voltage or attenuation. The resistors used in the attenuator are adjusted only to within 5% of their nominal values, thus permitting a considerable economy in manufacturing and a consequent reduction of the price of the instrument. More complicated and accurate attenuation systems can be included on special order, for those special cases where they may become necessary, but the standard system should suffice for most users.

The same considerations are true to some extent of the oscillator which determines the fundamental frequency in the Model 71. Since no very accurate knowledge of the frequency of test is usually required in the square wave technique, no attempt has been made to make the Model 71 an accurate standard of frequency. The frequency dials are individually calibrated to eliminate possible manufacturing differences in the variable resistors which are the frequency determining elements, but since these variable resistors are subject to possible change over their life and to short time changes due to temperature and humidity, no guarantees as to frequency accuracy can be made. To overcome this in those cases where it is considered a disadvantage, terminals have been provided by means of which a locking or synchronizing voltage may be injected into the oscillator circuit, so that the frequency can be stabilized by being made equal to an external frequency or to some harmonic or submultiple thereof.

The frequency-determining oscillator is of the relaxation or multivibrator type, using two 6J5 tubes. Coarse variation of frequency is obtained by changing the feedback condensers in 10:1 steps, the switch which accomplishes this being the lower-left control dial on the instrument's panel. The four steps of capacitance included in the standard instruments provide nominal ranges of 5-100, 50-1000, 500-10,000, and 5000 to 100,000 cps; the fine variation in each range is obtained by a dual variable resistor in the grid

circuits of the oscillator tubes, controlled by the upper left control dial on the panel. This range of fundamental frequencies should cover all normal testing requirements, but if an extension is needed for special cases, higher or lower frequency ranges can be readily added by connecting appropriate condensers to unused switch positions, as will be evident from the circuit diagram attached to this instruction book.

The output wave of the multivibrator type oscillator has the essential characteristic of square waves, the extremely short "flipover" period between the positive and negative half-cycles. The tops of the waves are not flat, but this can be remedied by arranging the output stage to be driven from cutoff on one side of the cycle to grid saturation on the other, thus flattening the tops. However, it is possible to improve performance in respect to short rise time and flatness of tops if an intermediate buffer-clipper stage is employed between the oscillator and output stages, and this stage has been included in the Model 71. The output of this CB stage is a square wave of about 60 volts peak amplitude, short rise time, and almost perfectly flat top, which when applied to the output stage and improved by the further clipping in this stage, emerges as a square wave of almost ideal characteristics. The rise time is of the order of 0.1 microsecond, this result being obtained largely through the use of the high-conductance 6J7 tubes in this stage; such high-frequency cutoff as is indicated by this rise time is due in large part to the unavoidable capacitance of the output circuits shunting the output resistance of 1500 ohms. Some improvement of the steepness of the wave front can be obtained by reducing the output impedance by shunting, at a sacrifice of output voltage since the output stage operates on a constant-current basis. This shunting can be done externally very readily at any time desired, hence no provision has been made in the standard instrument for it. The standard output impedance is 20 ohms per volt peak output, as will be evident from the circuit diagram, or 1500 ohms each side of ground for the maximum output voltage of 75 volts peak each side of ground.

Attenuation of this maximum voltage is provided for only one side of the output circuit by a simple voltage-divider type of attenuator. The voltage appearing across this attenuator is measured by a simple d.c. voltmeter circuit, the use of which is made possible by the characteristics of the square wave. Since current is flowing in the output tube during only half the cycle, the tube being cut off during the other half, current will flow through the voltmeter during only half the cycles, and always in the same direction. Thus the voltmeter will indicate just one-half of the peak voltage, and it is calibrated so that at the 1.0 point on its scale, indicating 75 peak volts of output, it is actually indicating 37.5 volts d.c. It will be evident that this relationship depends upon exact equality between the two half cycles of the applied wave, and that any inequality will result in an error of indication. Such

inequalities can result from differences between the two oscillator tubes, between the two feedback condensers, or between the two variable grid resistors, and by careful selection of components at the factory these differences are largely eliminated.

As mentioned above, the inclusion of the buffer-clipper stage considerably improved the performance of the square-wave generating system. However, it introduced problems of coupling the various stages together; it was found that the usual condenser and resistor coupling circuits made it impossible to obtain the quality of performance desired for this instrument, even if the fundamental frequency range were greatly reduced. The design was therefore carried through on a direct-coupling basis, with no coupling networks of any sort between the stages to introduce frequency discrimination. As a result, the amplification system of the Model VI produces square waves having perfectly flat tops, even at very low fundamental frequencies. Frequencies as low as one cycle in several seconds have been obtained in experimental models, with no decrease of flatness of tops, and very little increase in the rise time, thus approaching very closely the theoretical ideal unit function (sometimes called Heaviside Unit Function).

The ideal flatness of top would be lost if it were necessary to include any coupling circuits between the output tubes and the equipment under test. Therefore, no series condensers are used, and in order to prevent the B supply voltage from appearing at the output terminals, the entire supply voltage system is reversed from conventional practice, the positive terminal being grounded and the tube cathodes all being at high negative potential. This departure is emphasized in the circuit diagram by inverting all of the circuit elements diagrammatically, placing the negative leads at the top of the figure and the ground positive busses at the bottom.

It will be seen that this arrangement will not produce, from the single-ended connection obtained between one tube and ground, a square wave whose axis is at ground potential. Rather, one peak of the wave is at ground, being generated when the output tube is on its cutoff half cycle; the other half of the wave being negative to ground by the whole peak value of the wave, being generated when the tube is on its conducting half cycle.

Thus, the output wave produced by the single-ended connection is all negative to ground, or in more conventional terminology, it contains a d.c. component equal to half its peak to peak value, and negative in sign. In those cases where this d.c. component is significant, it can be altered or removed by means of a series blocking

battery, or by means of a large series condenser in some applications. No series condenser should ever be included, however, unless consideration of the load into which it works shows that no considerable low-frequency discrimination will be introduced.

It is recommended that the following references be studied for a more comprehensive understanding of the fundamentals of square wave testing:

BIBLIOGRAPHY

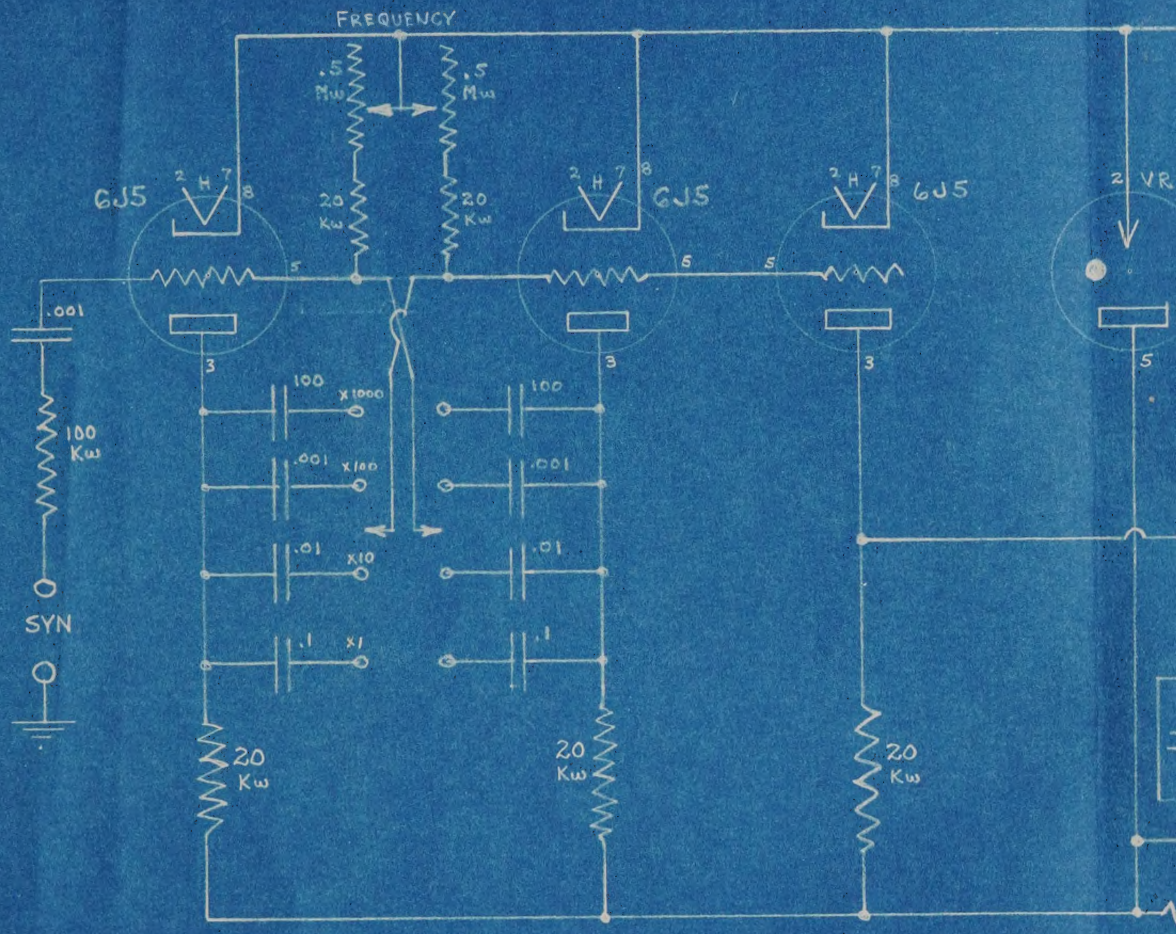
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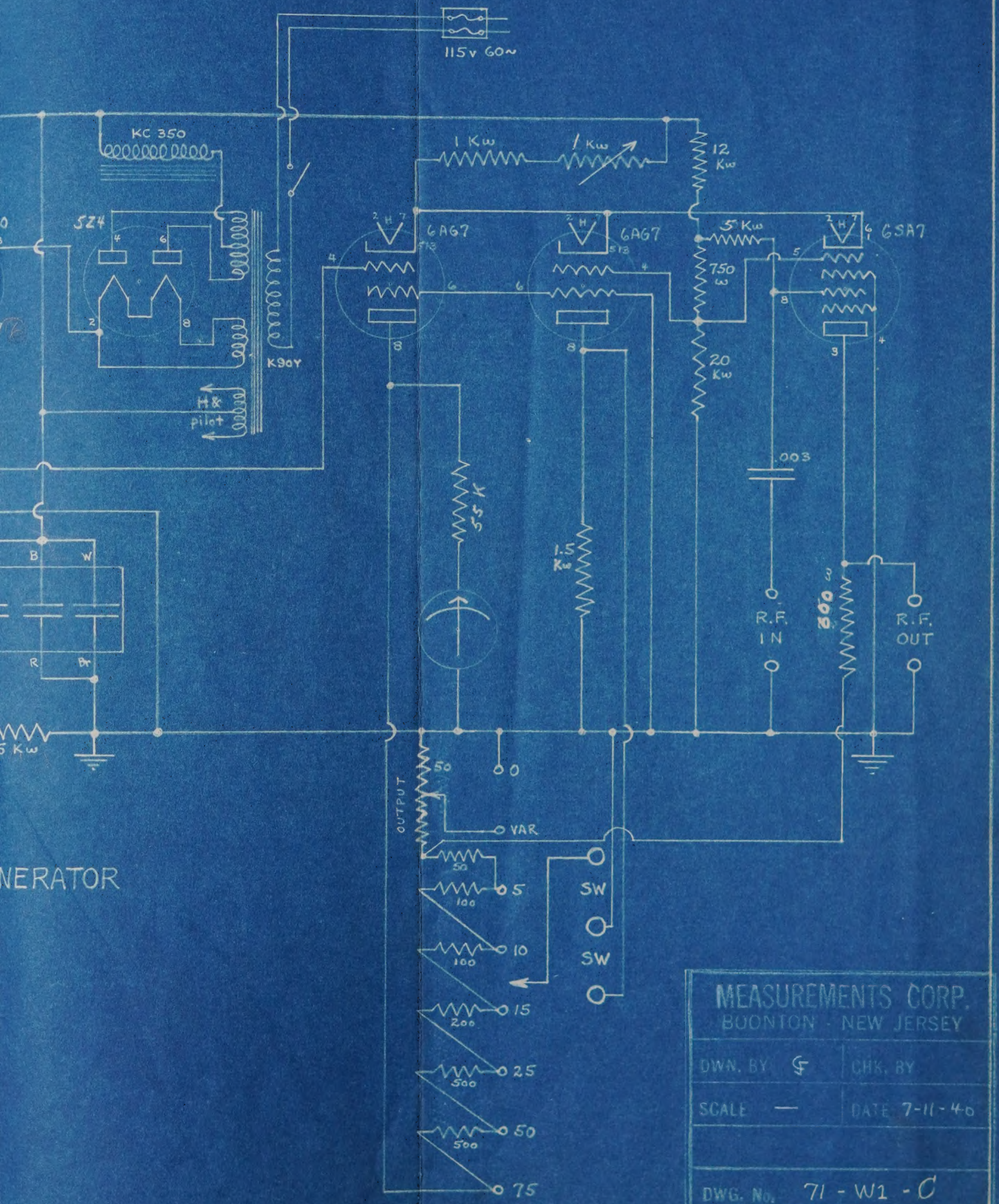
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5 L. B. Arguimbau, "Transient Response of a Two-Phase System",-General Radio Experimenter, Vol. 14, No.11, April, 1940.



MODEL 71 SQUARE WAVE G

Circuit Diagram



MEASUREMENTS CORP. BOONTON · NEW JERSEY	
DWN. BY GF	CHK. BY
SCALE —	DATE 7-11-40
DWG. No. 71 - W1 - C	

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